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16. ABSTRACT

This paper discusses the results of EPA's tests of five electrostatic collection concepts over the last 4 years: electric curtain, electrostatic scrubbing, electrstatic fiber beds, charged droplet scrubbing, and electrostatic effects on fabric filters. Of the five, electrostatic scrubbing and those concepts using filters prove to be the best collection methods. Electrostatic scrubbing efficiency depends on the presence of an ambient electric field and the charge of the droplets. Charged droplets in an ambient electric field use only a minimal amount of energy and are more efficient at 0.5 and 1.0 micrometers. Collection efficiency with fabric or fiber filters depends on the medium: precharging enhances the performance of fiber filters, making them more efficient than fabric filters. The electric curtain collection method is efficient at low velocities, but for fly ash collection under stack conditions, this method is not effective.

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Pollution	Pollution Control	13B
Dust	Stationary Sources	11G
Scrubbers	Electrostatics	07A
Fabrics	Particulate	11E
Fibers	Electric Curtain	
Fly Ash	Charged Droplets	21B

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ADVANCED ELECTROSTATIC COLLECTION CONCEPTS

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Of the advanced electrostatic collection concepts studied, those employing water droplets or filters have demonstrated enhanced performance and should be considered for future applications. Electrostatic collection with water drops shows high removal efficiencies for 0.5 μm particles which are difficult to capture. Electrostatic collection with filters shows the potential for operation at either lower pressure drops or higher filtration rates.

The conventional approach in using electrostatics for abatement of airborne particle emissions is to charge the particles and collect them in a high voltage DC field. Both the charging of the particles and the collection can be accomplished in a single device. Alternatives to this approach involve precharging the particles and subsequent collection of the charged particles in a separate device. This collection device may use electrostatic forces or may introduce a collecting medium such as water droplets or a filter.

Possible electrostatic collection concepts are given in Table I. Details for these concepts are given below. In general, the entries in Table I reflect the three major categories of collection mechanisms; that is, electric field effects, scrubbing, and filtration. In the case of the latter two, the combination of electrostatic effects with the conventional mechanisms permits enhanced performance of the new device as compared with conventional devices of the same type. It was the possibility of enhanced performance that was the stimulus for EPA's involvement in developing advanced electrostatic collection concepts. After 4 years of work under seven contracts and grants many of the projects have produced conclusive results and the remainder continue to indicate potential success. This paper summarizes the progress made in developing advanced electrostatic collection concepts.

Electrostatic Collection with Droplets

The use of water droplets in an electrostatic collection device will differ according to whether the drops are charged or not and whether there is an ambient electric field. The case of no ambient field with the drops charged to an opposite sign to that of the particles is the usual configuration for a charged droplet scrubber. The scrubber consists of three chambers: (1) a corona discharge section for particle charging; (2) a spray chamber which introduces oppositely charged droplets; and (3) a mist eliminator. A charged droplet scrubber tested by EPA is the University of

Table I. Electrostatic collection concepts.

Name	Collection by means of	EPA Activity
Electric curtain	AC electric fields	Grant 803047, U. of Illinois
Electrostatic scrubbing	Electric fields and water droplets	Contract 68-02-0250, MIT Contract 68-02-1345, TRW
Charged droplet scrubbing	Water droplets	Grant 803278, U. of Washington Grant 804393, U. of Washington
Electrostatic fiber beds	Filter fibers	Grant 801581, Battelle Northwest
Electrostatic effects in fabric filters	Filter fabric	Grant 803020, Carnegie-Mellon U.

Washington electrostatic scrubber.[1] The scrubber was tested on a coal fired boiler side stream at 1655 to 1802 am^3/hr and on an electric arc steel furnace side stream at 1754 to 3031 am^3/hr. In both cases the overall efficiency was greater than 96%; performance of the scrubber was greatly influenced by the water to gas ratio. At the coal fired boiler site, doubling the water to gas ratio from 0.32 to 0.76 liters/am^3 halved the overall penetration from 3.9 to 1.9%. The power consumption was approximately 13 w/(m^3/min) and the residence time was 8 sec.

A second case is one in which there is no ambient field and the drops are not charged. This case may be called an electrostatically augmented scrubber and consists of two sections: a corona discharge section and a conventional scrubber. An electrostatically augmented scrubber tested by EPA is the Air Pollution Systems electrostatic scrubber.[2] This scrubber consists of a venturi scrubber with an electrode placed upstream to do the precharging. Using a test aerosol of redispersed TiO_2 with a mass median diameter of 1 μm and a geometric deviation of 2.2, the overall collection efficiency ranged from 83–97%. Since the scrubber is primarily a venturi, an important consideration is the pressure drop which was 43 cm WC for the system including a cyclone entrainment separator. Summing the power consumption for the pressure drop and the ionizer, the total energy requirement was 80 w/(m^3/min).

A third case, which does not use a precharging section as other devices in this section do, is one with an ambient field and charge on the drops imposed by the electric field. In this device, referred to as a charged droplet precipitator, there is only one chamber where the water is introduced into the middle from nozzles at high voltage. The drops leave the nozzle with a charge and are accelerated to the walls by the electric field. A charged droplet precipitator tested by EPA is the TRW charged droplet scrubber which was demonstrated on a coking oven battery exhaust.[3] The test unit has a capacity of 31,000 m^3/hr at a gas flow rate of 1.83 m/s with a residence time of 3 sec. The scrubber operated with a low water rate of less than 0.14 liters/am^3 (1 gal/1000 acf). The total power consumption was 28–42 w/(m^3/min). During the demonstration testing it was found that the TRW unit could be operated with very infrequent wall wash and that the overall efficiency (approximately 94%) was highest under this condition.

A comparison of advanced electrostatic concepts using water droplet collectors is given in Table II. These results are from development programs, as noted in the introduction, or from field tests. In comparing the performance of these concepts, it is important to note that water consumption rates can differ by an order of magnitude and power consumption by a factor of 6. The highest power consumption, however, corresponds to the shortest residence time requirement and for these three concepts the residence time requirements varied inversely to power requirements. All concepts provide high overall collection efficiencies and high efficiencies in removing the 0.5 μm diameter particle. It has been noted previously that penetrations range from 30 to 50% for 0.5 μm particles in conventional scrubbers.[4] Since penetrations for the 0.5 μm particle through the advanced electrostatic collection devices range from 1 to 10%, these concepts have demonstrated significantly enhanced performance. It is possible to increase the pressure drop in a venturi scrubber to decrease the penetration of 0.5 μm particles to 10%. The pressure drop required can be estimated by Calvert's equation 5.3.6-12 in the *Scrubber Handbook*.[5] The energy requirement for a venturi scrubber to collect 90% at a 0.5 μm particle size is 325 w/(m^3/min). This is an order of magnitude higher than the 13–80 w/(m^3/min) reported for the same performance with electrostatic droplet concepts.

Table II. Comparison of electrostatic droplet concepts.

Unit Tested	Overall Efficiency %	Power Requirement w/(m^3/min)	Water to gas Ratio (l/Am^3)	Percent efficiency at 0.5 μm	1.0 μm
U. of Washington[a] Electrostatic Scrubber	98.1–99.5	13	0.76–0.77	99	97.5
U. of Washington[b]	96.4–98.6	13	2.23–2.29	95	97
APS electrostatic scrubber	83–97	80	1.44	96	90
TRW charged droplet scrubber	93.5[c]	28–42	0.11–0.13	90	85–95

[a] At a coal fired boiler.
[b] At an electric arc furnace.
[c] Pooled data with no wall wash.

Electrostatic Collection with Filters

The use of filters with electrostatics will vary according to whether the filter uses fibers or a fabric as the collector. If it is a fiber collector, precharging the particles will enhance the collection efficiency. If it is a fabric collector, precharging the particles will change the nature of the deposited cake and correspondingly lower the pressure drop and may improve the collection efficiency.

The first case, referred to as an electrostatic fiber bed, was studied by Battelle Northwest.[6] The three aerosols studied (NH_4Cl, Na_2O, and MgO) had mass median diameters of less than 1 μm. The freshly generated particles were drawn first through a corona charging section and then through the fiber bed. The fiber beds had a void fraction of 0.96, were 15 or 30 cm thick, and were composed of stainless steel, polypropylene, or Teflon. Using a 30 cm bed, collection efficiency was greater than 95% for bed velocities up to 1 m/s with a pressure drop through the clean bed of less than 1 cm WC.

The second case, that of precharging particles before a fabric filter or electrostatically augmented filter, has been studied by Carnegie-Mellon University.[7] The filter was a 10 cm ID by 30 cm long bag made of woven material such as polypropylene without antistatic treatment. The aerosol was a silica dust charged either by impingement against a tungsten carbide surface or by corona discharge. The bags were pulse-jet cleaned. At an air-to-cloth ratio of 6, the electrostatically augmented filter had a pressure drop of 6.4 cm WC; a comparable bag without precharged particles had a pressure drop of 16.5 cm WC. Similar results have been reported by American Precision Industries, Inc.[8] Testing their electrostatically augmented filter called the APITRON, American Precision Industries reports a reduction in pressure drop from 10 cm WC for a conventional filter to approximately 1 cm WC for the APITRON maintaining the same filtration rate on a steel furnace fume. If the pressure drop is the same for both filter types, the APITRON may be operated at a filtration rate 4 times greater. Since electrostatically augmented filters have demonstrated significant reductions in pressure drop at the same filtration rate (or significant improvements in filtra-

tion rate at the same pressure drop in conventional filters), this concept also has proven enhanced performance with electrostatics.

Electrostatic Collection with AC Fields

In a recently completed study, the University of Illinois determined the feasibility of collecting charged particles with AC fields.[9] The device is called an electric curtain and is shown in Figure 1 in its vertical planar form. The vertical plane of parallel rods is to act as a barrier to charged particles. The rods have a high voltage AC field and are energized either by single phase producing a standing wave electric curtain or by six phase producing a traveling wave electric curtain. Adjacent rods are correspondingly out of phase. A development and description of the force on a charged particle by an electric curtain is given by Masuda.[10]

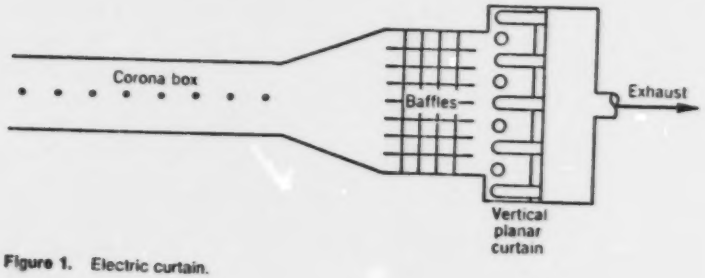

Figure 1. Electric curtain.

In the University of Illinois study, tests were conducted with the planar electric curtain in both a vertical and horizontal orientation as well as at a 45° incline. The inclined plane experiments were first in order to observe the trajectories of charged particles falling onto the curtain. Samples of lycopodium, silica, feldspar, and Detroit Edison fly ash were repelled by the curtain and accumulated at the bottom end of the incline. With the electric curtain in a horizontal orientation, the electrodes were energized with a six phase AC voltage just below the breakdown strength of air. The force from the electric curtain was sufficient to support all test samples against gravity and to move them in a horizontal direction as dictated by the traveling wave.

When the electric curtain was in a vertical orientation, it was found that fly ash was the most difficult of the test samples to stop and that fly ash could not be stopped at air velocities above approximately 1 cm/sec. The failure to stop fly ash at higher velocities was thought to be possibly attributed to poor charging, turbulent air flow patterns, and the limitation of curtain field strength to the breakdown value of air. To overcome the last of these, a double curtain using two rows of rods was constructed. Unfortunately, the double curtain showed little improvement over the single curtain.

Conclusions

Of the advanced electrostatic collection concepts studied, those employing water droplets or filters have demonstrated enhanced performance and should be considered for future applications. Electrostatic collection with water drops shows high removal efficiencies for 0.5 μm particles which are difficult to capture. Electrostatic collection with filters shows the potential for operation at either lower pressure drops or higher filtration rates.

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